# PATENT SPECIFICATION

716,927

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COMPLETE SPECIFICATION.

## Improvements in or relating to Glass-to-Metal Seals.

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British Company, and ROBERT LEONARD BREADNER and CHARLES HENRY SIMMS, both of Research Laboratories, The General Electric Company Limited, Wembley, Middlesex, both British Subjects, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the manufacture of glass-to-metal seals of the kind wherein a tubular glass member is sealed to the end of a tubular metal member which is sufficiently thin and ductile at the region of sealing to yield under thermal expansion or contraction stresses and enable an enduring seal to be formed. Such seals are often used in the manufacture of electrical devices, and especially electric discharge devices, having sealed envelopes of which the said members form part.

The metal which has hitherto most often been used for the tubular metal member in the manufacture of seals of the kind referred to is copper, which has good electrical and heat conductivities, a high ductility and good working properties. Another metal which has similar properties favourable for its use in glass-to-metal seals is aluminium and this metal has further advantages such as cheapness, lightness of weight, and chemical passivity which might be very useful in some circumstances.

Aluminium has, however, several disadvantageous properties which have hitherto precluded its use in glass-to-metal seals of the kind referred to. Thus it has a relatively high thermal expansion coefficient (about $0{\cdot}23 \times 10^{-4}$ as compared with $0{\cdot}17 \times 10^{-4}$ for copper) and a relatively low melting point (about 650° C. as compared with about 1100° C. for copper); furthermore, when heated it forms an oxide which is mechanically weak at sealing temperature and is readily detached from the surface of the metal, which greatly adds to the difficulties of forming a seal.

The object of this invention is to overcome these difficulties and render possible the manufacture of seals of the kind referred to in which the tubular metal member is of aluminium.

According to the invention in the manufacture of a seal of the kind referred to wherein the tubular metal member is of aluminium, one end of the said member has the form of a thin-walled cone and is seated on a correspondingly conical-shaped part of a block of refractory heat-conductive material, a tubular glass member of relatively soft glass is applied over or within the metal cone so as to press the metal against the block over a circumferential zone of the metal cone away from the end of the tubular metal member, the refractory block is heated so that whilst the temperature of the metal member remains everywhere below its melting point, the end of the glass member is softened to cause it to seal to the metal cone over the said zone, and a pressure difference is established between the atmosphere within the interior of the tubular glass member and the atmosphere surrounding the exterior of the glass member so that the heat-softened end of the glass member is forced towards the metal cone by the excess pressure on the exterior or interior surface of the glass member and the area of sealing contact of the glass with the cone thereby caused progressively to increase.

The method in accordance with the invention has the advantage that by the indirect heating of the aluminium member by conduction from the refractory block, it is

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possible closely to control the temperature of the aluminium so that its temperature does not approach undesirably close to its melting point whilst at the same time attaining a sufficiently high temperature for the softening of the end of the tubular glass member; the statement that the latter is of relatively soft glass implies that its softening temperature is sufficiently below the melting temperature of the aluminium to enable the method in accordance with the invention to be applied. In general any glass whose viscosity at 625° C. is not more than $10^{8}$ poises can be used and this includes some of the glasses normally used for the envelopes of electric discharge devices.

The method of first sealing the glass to the aluminium cone over a circumferential zone and then blowing or collapsing the glass on to the cone so as to produce a progressive increase in the area of sealing contact reduces the possibility of the seal being spoilt by the detachment of oxide from the aluminium surface, which might otherwise occur if there was any appreciable sliding of the glass surface over the metal surface, such as might result from attempts to produce the necessary sealing purely by mechanically pressing the tube against the cone under a force directed along their common axis. The aluminium cone should, of course, be cleaned before use, for example by immersion in caustic soda solution, for degreasing and to remove any loose surface metal or oxide.

The block of refractory material, which acts as a heat reservoir, preferably consists of an oxidation-resistant iron alloy, such as an iron-chromium-nickel alloy, and its temperature is preferably measured for controlling the heating of the block during the sealing operation, for example by means of a thermo-couple embedded therein; in some cases it may be desirable to associate the thermo-couple with control means for the heating means so that the heating of the block is arranged to be controlled automatically; thus the voltage derived from the thermo-couple may be arranged to control a servo system which regulates the heating intensity of a burner arranged for the heating of the block.

Preferably the wall of the aluminium cone is rolled to a feather edge, the angle of taper of the wall thickness being preferably about 3° to 5°.

One method in accordance with the invention will now be described by way of example with reference to Figures 1 and 2 of the schematic drawing accompanying the Provisional Specification, each of which Figures shows a section containing the axis of the apparatus used, each at a different stage in the carrying out of the method.

Referring now to Figure 1, a cylindrical block 1 of an oxidation-resistant iron-chromium-nickel alloy is perforated by a central hole 2 which at its upper end flares outwards to form a conical recess 3.

Into the hole 2 is inserted the closed end 4 of an aluminium tube, the upper end of which is flared outwards to form a cone 5 of the same apical angle as the recess 3 in the block 1, and of tapering wall thickness; the closed end 4 of the aluminium tube is a loose fit within the hole 2 whilst the cone 5 fits snugly against the sides of the recess 3, the end of the cone lying flush with, or projecting slightly beyond, the surface of the block. Here it may be noted that the apical angle of the cone 5 and recess 3 has, for the sake of illustrating the invention more clearly, been shown much greater than it would be in practice, as will appear from figures which will be given later.

Into the mouth of the cone 5 is inserted the end of a glass tube 6, the upper end of which is closed by a stopper 7 through which passes a pipe 8 which can be put in communication with a source of compressed air, not shown.

The block 1 is fitted with a thermo-couple 9 by means of which the temperature of the block is observed, whilst the block is heated by means of a ring of burners (not shown) playing on its sides, and the heating of the block is controlled so that the temperature of the aluminium cone remains at about 625° C.

During the heating a slight downward pressure is applied along the axis of the tube 6, a clamp 10 for the tube being left open for this purpose; this pressure is arranged to be just sufficient to cause the end 11 of the glass tube 6 to soften and seal to the aluminium, whereupon the clamp 10 is closed to hold the tube 6 fast and the downward pressure removed whilst compressed air is introduced into the tube through the pipe 8, as indicated by the arrow in Figure 2, so that the end 11 of the glass tube is progressively softened and blown on to the surface of the cone 5 to increase the area of sealing, as illustrated in Figure 2, in which corresponding reference numerals denote the same parts as in Figure 1.

In one particular example of the process described with reference to Figures 1 and 2, the aluminium tube was of internal diameter 0·375 inches and wall thickness 0·065 inches, the apical angle of the coned end 5 being about 20°, and the angle of taper of the wall thickness was 3°. The aluminium was of high purity and the coned end was cleaned before use by immersion in caustic soda solution.

The glass tube 6 was of outside diameter 0·5 inches, and wall thickness 0·04 inches and the glass has approximately the following composition:—

| | |
|---|---|
| $SiO_2$ | 55·5% |
| PbO | 30·0% |
| $Al_2O_3$ | 1·0% |
| $Na_2O$ | 5·2% |
| $K_2O$ | 7·5% |
| CaO | 0·5% |
| MgO | 0·3% |

In carrying out the method in this particular example, the aluminium cone was heated to a temperature of about 625° C., the mechanical pressure applied along the axis of the glass tube, as indicated by the arrow in Figure 1, was equivalent to about 2 lb. weight, and the pressure of the compressed air introduced was about 10 lb. per square inch, the sealing process from the introduction of the compressed air taking about 15 minutes.

It will be appreciated that the invention is not restricted to the form shown in Figures 1 and 2 and could, for example, in some cases alternatively be performed with an aluminium cone formed by the inwardly tapered end of a tube whose other end fits over a conically terminated boss projecting from the refractory heat-conductive block, the glass tube then fitting over the cone and the pressure difference for producing the progressive sealing of the glass to the cone being produced by evacuating the interior of the glass tube so as to cause the glass to collapse to the cone.

It will be understood that in this Specification the term aluminium includes alloys of aluminium which are suitable for use in forming seals of the kind specified, by the method in accordance with the invention.

What we claim is:—

1. The manufacture of a glass-to-metal seal of the kind referred to, wherein the said tubular metal member is of aluminium, one end of the said metal member has the form of a thin-walled cone and is seated on a correspondingly conical-shaped part of a block of refractory heat conductive material, a tubular glass member of relatively soft glass is applied over or within the metal cone so as to press the metal against the block over a circumferential zone of the metal cone away from the end of the tubular metal member, the refractory block is heated so that whilst the temperature of the metal member remains everywhere below its melting point the end of the glass member is softened to cause it to seal to the metal cone over the said zone, and a pressure difference is established between the atmosphere within the interior of the tubular glass member and the atmosphere surrounding the exterior of the glass member so that the heat softened end of the glass member is forced towards the metal cone by the excess pressure on the exterior or interior surface of the glass member and the area of sealing contact of the glass with the cone thereby caused progressively to increase.

2. The manufacture according to Claim 1, wherein the wall of the cone, formed at one end of the said tubular metal member, is rolled to a feather edge, the angle of taper of the wall thickness being approximately 3° to 5°.

3. The manufacture according to Claim 1 or 2, wherein the glass from which the said tubular glass member is formed is such that its viscosity at a temperature of 625° C. is not more than $10^8$ poises.

4. The manufacture according to Claim 1, 2 or 3, wherein the said block of refractory material consists of an oxidation-resistant iron alloy, for example an iron-chromium-nickel alloy.

5. The manufacture according to any preceding Claim, wherein the temperature of the said block of refractory material is measured, for controlling the heating of the block during the sealing operation, by means of a thermo-couple embedded therein.

6. The manufacture of a seal substantially as shown in and hereinbefore described with reference to Figure 1 and Figure 2 of the drawing accompanying the Provisional Specification.

7. A glass-to-aluminium seal which has been manufactured in accordance with any preceding claim.

For the Applicants,
J. E. M. HOLLAND,
Chartered Patent Agent.

## PROVISIONAL SPECIFICATION.

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This invention relates to the manufacture of glass-to-metal seals of the kind wherein a tubular glass member is sealed to the end of a tubular metal member which is suffi-

ciently thin and ductile at the region of sealing to yield under thermal expansion or contraction stresses and enable an enduring seal to be formed. Such seals are often used in the manufacture of electrical devices, and especially electric discharge devices, having sealed envelopes of which the said members form part.

The metal which has hitherto most often been used for the tubular metal member in the manufacture of seals of the kind referred to is copper, which has good electrical and heat conductivities, a high ductility and good working properties. Another metal which has similar properties favourable for its use in glass-to-metal seals is aluminium and this metal has further advantages such as cheapness, lightness of weight, and chemical passivity which might be very useful in some circumstances.

Aluminium has, however, several disadvantageous properties which have hitherto precluded its use in glass-to-metal seals of the kind referred to. Thus it has a relatively high thermal expansion coefficient (about $0{\cdot}23 \times 10^{-4}$ as compared with $0{\cdot}17 \times 10^{-4}$ for copper) and a relatively low melting point (about 650° C. as compared with about 1100° C. for copper): furthermore, when heated it forms an oxide which is mechanically weak at sealing temperature and is readily detached from the surface of the metal, which greatly adds to the difficulties of forming a seal.

The object of this invention is to overcome these difficulties and render possible the manufacture of seals of the kind referred to in which the tubular member is of aluminium.

According to the invention in the manufacture of a seal of the kind referred to wherein the tubular metal member is of aluminium, an end of the said member has the form of a thin-walled cone and is seated on a correspondingly conical-shaped part of a block of refractory heat-conductive material, tubular glass member of relatively soft glass is applied over or within the metal cone so as to press the metal against the block over a circumferential zone of the metal cone away from the end of the tubular metal member, the refractory block is heated so that whilst the temperature of the metal member remains everywhere below its melting point, the end of the glass member is softened to cause it to seal to the metal cone over the said zone, and a pressure difference is established between the interior and exterior of the tubular glass member such that the heat-softened end of the glass member is forced towards the metal cone by the excess pressure and the area of sealing contact of the glass with the cone thereby caused progressively to increase.

The method in accordance with the invention has the advantage that by the indirect heating of the aluminium member by conduction from the refractory block, it is possible closely to control the temperature of the aluminium to below its melting point whilst at the same time attaining a sufficiently high temperature for the softening of the end of the tubular glass member; the statement that the latter is of relatively soft glass implies that its softening temperature is sufficiently below the melting temperature of the aluminium to enable the method in accordance with the invention to be applied. In general any glass whose viscosity at 625° C. is not more than $10^8$ poises can be used and this includes most of the glasses normally used for the envelopes of electric discharge devices.

The method of first sealing the glass to the aluminium cone over a circumferential zone and then blowing or collapsing the glass on to the cone so as to produce a progressive increase in the area of sealing contact reduces the possibility of the seal being spoilt by the detachment of oxide from the aluminium surface, which might otherwise occur if there was any appreciable sliding of the glass surface over the metal surface, such as might result from attempts to produce the necessary sealing purely by mechanically pressing the tube against the cone under a force directed along their common axis. The aluminium cone should, of course, be cleaned before use, for example by immersion in caustic soda solution, for degreasing and to remove any loose surface metal or oxide.

The block of refractory material, which acts as a heat reservoir, preferably consists of an oxidation-resistant iron alloy, such as an iron-copper-nickel alloy, and its temperature is preferably measured for controlling during the sealing operation by means of a thermo-couple embedded therein; in some cases it may be desirable to associate the thermo-couple with control means for the heating means so that the latter is arranged to be controlled automatically.

Preferably the aluminium cone is rolled to a feather edge, the angle of taper of the wall thickness being preferably about 3° to 5°.

One method in accordance with the invention will now be described by way of example with reference to Figures 1 and 2 of the accompanying schematic drawing, which each shows a section containing the axis of the apparatus used, each at a different stage in the carrying out of the method.

Referring now to Figure 1, a cylindrical block 1 of an oxidation-resistant iron-copper-nickel alloy is perforated by a central hole 2

which at its upper end flares outwards to form a conical recess 3.

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It will be appreciated that the invention is not restricted to the form shown in Figures 1 and 2 and could, for example, in some cases alternatively be performed with the aluminium cone inwardly tapered and fitting over a conical boss on the refractory heat-conductive block, the glass tube then fitting over the cone and the pressure difference for producing the progressive sealing of the glass to the cone being produced by evacuating the interior of the glass tube so as to cause the glass to collapse to the cone.

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For the Applicants,
J. E. M. HOLLAND,
Chartered Patent Agent.

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716,927 PROVISIONAL SPECIFICATION

I SHEET *This drawing is a reproduction of the Original on a reduced scale.*

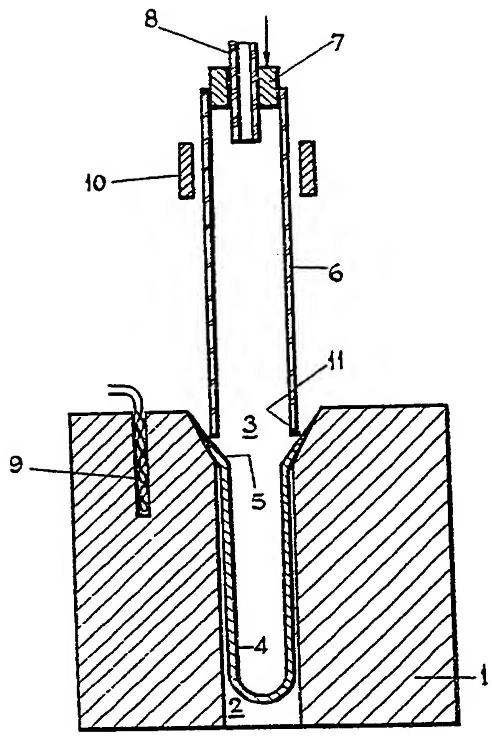


FIG. 1.

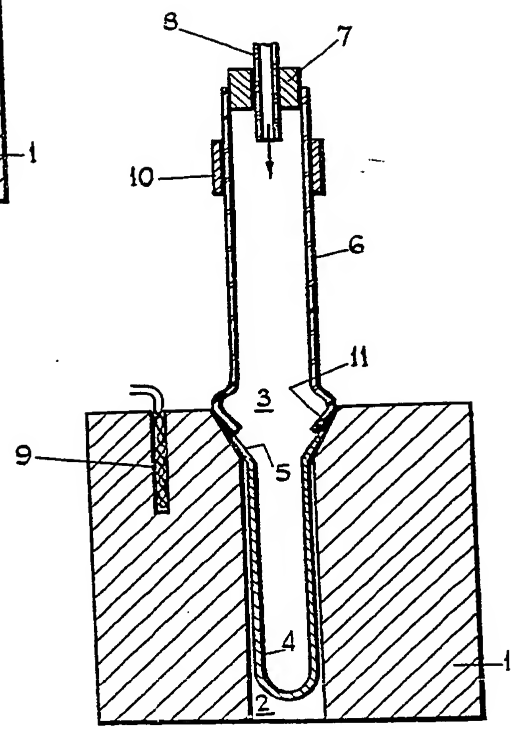


FIG. 2.